UBAS

University of Bergen Archaeological Series

The Stone Age Conference in Bergen 2017

Dag Erik Færø Olsen (ed.)

UNIVERSITY OF BERGEN

12

2022

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As clear as crystal? An attempt at sourcing hydrothermal quartz crystals from the Early Mesolithic site 'Mohalsen-I', Vega Island, Norway using LA-ICP-MS and SEM-CL

This article describes an attempt at sourcing hydrothermal quartz crystals from the Early Mesolithic site Mohalsen-I by comparing four pieces of debitage with quartz crystal samples from 19 known quartz crystal occurrences in Norway. Through identifying a possible source, the hope was that we could shed light on mobility patterns and raw material procurement strategies in the research area. The samples were analysed using laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) and scanning electron microscopy cathodoluminescence (SEM-CL). Through analysing SEM-CL images and the chemical composition of five samples from the Berglia-Glassberget occurrence in Lierne, we found similar structural features and chemical concentrations of selected trace elements in the samples. This indicates that the method is a viable approach to sourcing hydrothermal quartz crystals from archaeological contexts. However, no clear parallel for the samples from Mohalsen-I was discovered, indicating that the source is not among the quartz crystal occurrences analysed here. The research conducted will serve as a basis for potential future investigations and as a reference for similar studies.

Introduction

This article aims to highlight the findings from a recent provenance study of quartz crystal debitage from the Early Mesolithic site Mohalsen-I (see Fig. 1) on Vega Island, Norway (Spjelkavik 2016, Müller *et al.* 2018). The site was first excavated in 1974 (Alterskjær 1975, 1985), and later as a rescue excavation in 2012 and 2013 due to intensive aeolian erosion of the area (Lorentzen 2013, 2014). Though flint clearly dominates as the chosen lithic raw material on the site, a relatively large amount of quartz crystal tools, blades and debitage was collected. The flakes clearly show that they stem from large single quartz crystals (> 5 cm in size), which can be found only in a few Norwegian mineral occurrences. This sparked an interest in the provenance of the crystals. Where have these crystals been collected? Can they hint at possible trading, mobility patterns and lines of interaction?

With the increasing focus on varying migration patterns relating to the pioneer settlement of the Norwegian coast (see Kleppe 2014), it is interesting to consider the role of the settlement traces on Vega Island. As the inland ice sheet in this area would have been considerably closer to the contemporary coastline than further south and north in Norway (see Fig. 4), it seems unlikely that the mountainous regions would have been utilised to the same extent as the high mountain plateaus of western (Bang-Andersen 2003) and central Norway (Breivik and Callanan 2016). As the presence of an 'obligatory' small amount of quartz and quartz crystal on Early Mesolithic coastal sites in western Norway often is interpreted as the result of high mountain expeditions (Waraas 2001, p. 103), the relatively high amount of quartz crystal on the Mohalsen-I site warrants further inspection. There are few known Early Mesolithic sites along the coast of Nordland (see Breivik 2016) – could the quartz crystal debitage serve as a proxy to indicate inland mobility in this period? The main objective of this paper is thus to establish whether it is possible to trace quartz crystal debitage from an archaeological assemblage to a possible source, and to briefly investigate the role of quartz crystal in Early Mesolithic assemblages in central Norway.

The study combines scanning electron microscopy (SEM), scanning electron microscopy cathodoluminescence (SEM-CL) and laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) analyses to investigate the petrography and geochemical composition of quartz crystal samples from the site, compared with samples from known natural quartz crystal occurrences in central, western and southern Norway. The premise for the study is that structural traits, such as growth zoning and other internal structures of the crystals visualised by SEM-CL, combined with trace elemental analysis will provide a 'signature' or 'fingerprint' for each quartz crystal site. The internal textures and trace element content are unique to the crystals, which come from the same occurrence because they reflect the formation conditions and the crystal growth history at this site. A recent provenance study of quartz grains in marine sediments off the coast of Spitsbergen (Müller and Knies 2013) has revealed the potential in using LA-ICP-MS, SEM and SEM-CL for this purpose. Provenance studies of hydrothermal quartz (crystals formed by low to moderate temperature [50 to 600 °C] precipitation from an aqueous fluid) in archaeological research have seemingly not been attempted before, though attempts have been made to source pegmatitic (magmatic) quartz (e.g. Halavínová and Přichystal 2008, ten Bruggencate *et al.* 2013).

Mohalsen-I – an Early Mesolithic site on Vega Island, Norway

There are few Early Mesolithic sites in this part of Norway (see overview in Breivik 2016). This makes the sites on Vega Island interesting with respect to the earliest settlement phase of Norway and the development of adaptation and mobility in the Early Mesolithic. Because of the high level of isostatic rebound in the area and distance to the mainland (approximately 20 km), Vega Island has been referred to as an excellent 'laboratory' for Stone Age research (Bjerck 1989, p. 45). In the following, I will give a brief presentation of the Mohalsen-I site and the geology of Vega Island.

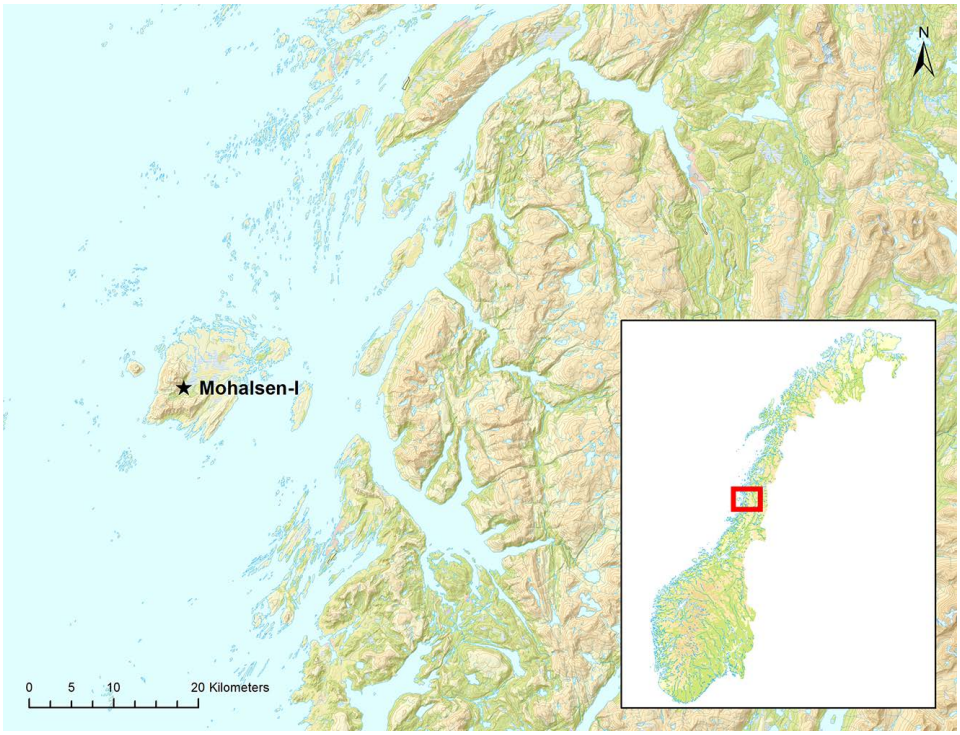

***Figure 1**: Map showing the location of the Mohalsen-I site. Map by Skule O. S. Spjelkavik.*

The Early Mesolithic landscape

Vega Island is situated 20 km off the Norwegian coast, near the town of Brønnøysund, approximately 110 km south of the polar circle (Fig. 1). It covers an area of 108 km^2 and comprises a small mountain range on the south-west side of the island, while the rest is dominated by a strand flat – a flat erosion surface typical of the coastal areas in this part of Norway (Holtedahl 1998). However, due to isostatic uplift since the Last Glacial Period, the island would have been considerably smaller at the time Mohalsen-I was in use (Fig. 2).

During the Early Mesolithic (9500–8000 BC), the island would have mainly consisted of the steep mountains Røsstinden (737 m.a.s.l.), Trollvasstinden (801 m.a.s.l.) and Vegtindan (661 m.a.s.l.). Areas suitable for habitation would primarily have consisted of a small brim of land along the base of the mountain chain, in addition to Vegdalsskaret – a rocky mountain pass crossing the island east to west between Røsstinden and Vegtindan. It is probable that the shoreline during the Early Mesolithic habitation phase at Mohalsen-I would have been situated around 70–80 m.a.s.l. This is based on an interpretation of the surrounding landscape, and the theory that the sites were oriented towards the marine environment and located close to natural harbours (Bjerck 1990). Under these conditions, the site would have been located on a low, rocky point, in a wide northeast facing bay, with a small skerry in the waters just east of the site (Fig. 2). The waters around Vega Island, today dominated by skerries and islets, would have been open and exposed to winds from nearly every direction.

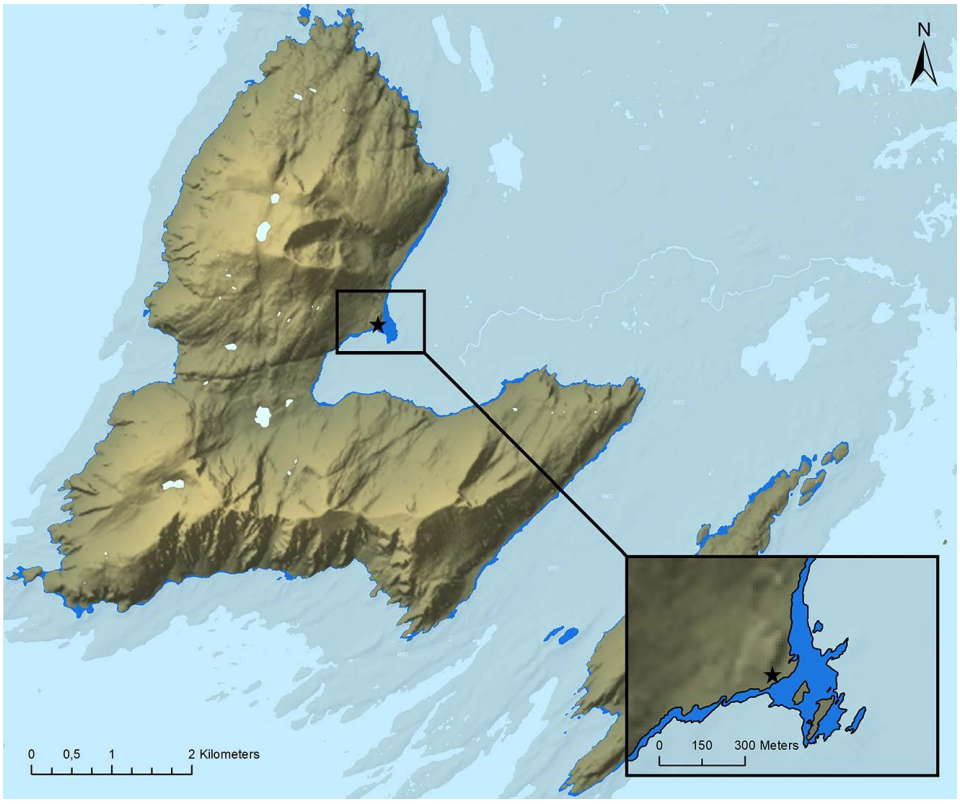

***Figure 2**: Map showing Vega Island with sea level positioned at 80 m.a.s.l. and 75 m.a.s.l. (marked with dark blue). The Mohalsen-I site is marked with a star. Map by Skule O. S. Spjelkavik.*

The geology of Vega

The bedrock of Vega is dominated by granodiorite and granite of the Ordovician (c. 475 Ma) Vega intrusive complex in the south, and marble, schist and gneiss of the Caledonian Uppermost Allochthon in the north (Marko *et al.* 2014). During the Early Mesolithic, only the parts of the island consisting of granodiorite, and to some extent the marble and calc-silicate (contact-metamorphosed marble when the granodiorite melt emplaced), would have been above sea level. The rest would have been inundated by seawater and out of reach. Hydrothermal veins, which could have produced quartz crystals > 5 cm, do not occur on Vega Island. This suggests that the hydrothermal quartz crystals on Mohalsen-I originate from somewhere else.

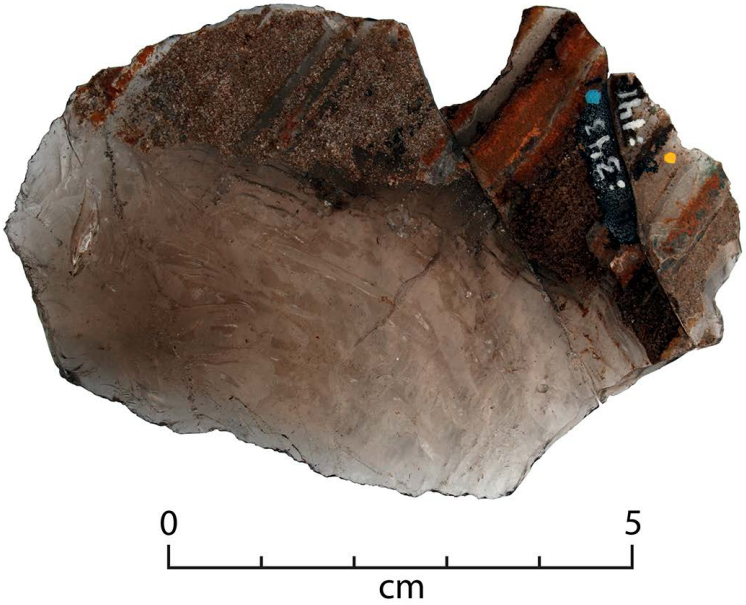

***Figure 3**: T25950:416, 343 and 141. Example of quartz crystal informal tool from Mohalsen-I. The flakes have been glued together as part of the research related to a recent master's thesis by Sæther (2017). Photo: Skule O. S. Spjelkavik.*

Quartz crystals could, however, have been found in moraine sediments, especially the large north–south-oriented terminal moraine located on the western central part of the island (Andersen *et al.* 1981, Fjalstad 1990). The excavations in 2012 and 2013 indicated that the site itself is situated on moraine sediments (B. Skar pers. comm.), though this is not indicated by the geological survey of the area. Moraines and beach deposits around Mohalsen-I could thereby constitute possible sources for lithic raw materials in the area. However, since large quartz crystals are rare in general, it is very unlikely that such large crystals occur in the moraine material on Vega Island.

Finds and radiocarbon dates

The compiled archaeological material collected from the site during the excavations in 1974, 2012 and 2013 consists of 7025 artefacts, mainly lithic debitage. Several Early Mesolithic diagnostic finds were discovered – such as single-edged points, burins, waste material from flake-adze production, and unifacial blade cores with acute striking angles. Flint (81.1%) was clearly the preferred raw material for tool production, but quartz crystal (9.6%) seems to have been favoured as well (Fig. 3). The remaining 9.3% of the finds consisted of various quartzites, vein quartz and some unclassified sedimentary rocks. Following a *chaîne opératoire*-analysis conducted by Sæther (2017), it was established that the site had been visited on several occasions and the material indicated that it was a multi-purpose dwelling site, as opposed to a butchering site or similar site resulting from a short-term stay.

Radiocarbon dating of charcoal collected from both the 1974 and 2012/2013 excavations confirms the typological dating, placing the activity at site between the EM2 and MM1

chronozone. The charcoal samples from the 2012 and 2013 excavations consisted of willow (*Salix*) and were dated to 9110–8460 cal. BC (2σ) (Ua-46949) and 9140–8620 cal. BC (2σ) (Ua-46947) (Lorentzen 2013, 2014). The samples from 1974 consisted of both willow (*Salix*) and small amounts of oak (*Quercus*) and the results of the dating had a considerably larger standard error: 9440–7825 cal. BC (2σ) (T-1807) and 8170–7040 cal. BC (2σ) (T-1808) (Alterskjær 1985). All dates have been recalibrated using OxCal v4.4.4. with the IntCal20 calibration curve (Ramsey 2009, Reimer et al. 2020).

Methods and materials

The geochemical analysis of the quartz crystal samples was conducted using LA-ICP-MS, whereas SEM and SEM-CL were used to produce electron and CL images of quartz crystal sections prepared as 300 μm thin sections mounted on standard glass slides (4.8 × 2.4 × 0.2 cm). The methods performed are presented below in general terms only (for further details on methodology, see Müller 2000, Müller *et al.* 2008, Müller and Knies 2013). Laboratorial details concerning the SEM and LA-ICP-MS instruments, and the reference materials utilised, are provided in Müller *et al.* (2018).

Samples

A total 23 quartz samples were prepared and analysed for this study. Four of these were selected from the lithic material retrieved from the excavations at Mohalsen in 2013 and consisted of micro-flakes. This was done to avoid destroying pieces that are more vital and disturb further research on the finds. On the basis of current knowledge, 15 hydrothermal quartz crystal occurrences in Norway were selected to serve as comparative material and as potential sources of the samples from Mohalsen-I. These chosen quartz occurrences cover most of the known Norwegian sites, which produced hydrothermal quartz crystals with sizes of > 5 cm. The archaeological finds from Mohalsen-I indicate that some of the quartz crystals utilised would have had a length greater than 5 cm, which is a relatively uncommon feature of quartz crystals occurring Norway (Mindat 2019 and references therein). Fourteen of the samples were kindly provided by Torgeir T. Garmo from his private mineral collection. The five remaining samples were collected at Berglia-Glassberget in Lierne, Trøndelag by Axel Müller in 2012 (see Müller *et al.* 2018 for occurrence description).

The sites Netoseter, Lyngeshø and Valdres were most likely covered by the inland ice sheet during the occupation phase at Mohalsen-I but were still included in the study as they were located close to the ice sheet margin. The Berglia-Glassberget occurrence was most likely covered by ice as well (see Fig. 4). However, since there exists an uncertainty regarding the extent of the ice sheet in this area (see Hughes *et al.* 2016), the samples from this occurrence were included in the study.

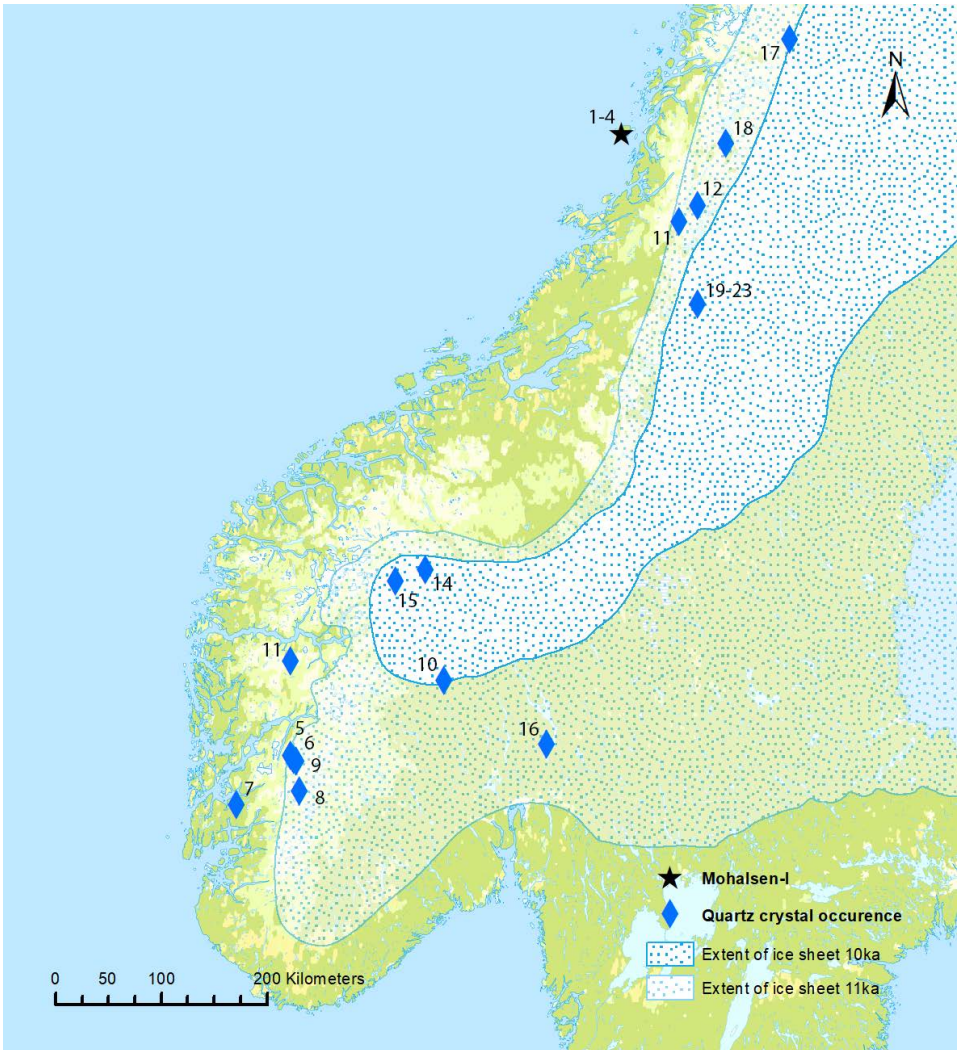

***Figure 4**: Map showing the quartz crystal occurrences analysed in this study. The numbers correspond to sample number (see Fig. 5). The extent of the ice sheet is after Hughes et al. (2016). Map by Skule O. S. Spjelkavik.*

During LA-ICP-MS analysis, the laser beam ablates the quartz sample over a raster of 300 × 150 µm with a depth varying between 40 and 100 µm. The quartz samples were thus prepared as special 300 µm-thick polished sections mounted on standard glass slides. The samples were prepared in Bochum, Germany, by Dettmar Dissection Technology GmbH.

For sake of clarity, the samples will hereafter be referred to by serial number (s.nr.), not corresponding museum ID number (T-number) or NGU number (see Fig. 5).

Sample nr.	NGU-nr.	Museum nr. (Tnr.)	Site	County
1	84751	T26109:581	Mohalsen-I, Vega	Nordland
2	84752	T26109:590	Mohalsen-I, Vega	Nordland
3	84753	T26109:591 (a)	Mohalsen-I, Vega	Nordland
4	84754	T26109:591 (b)	Mohalsen-I, Vega	Nordland
5	84777		Endenut	Hordaland
6	84779		Nibbenut	Hordaland
7	84780		Etne	Hordaland
8	84781		Svandalsflona	Telemark
9	84782		Matskorhæ	Hordaland
10	84783		Valdres	Oppland
11	84784		Vikafjell	Sogn og Fjordane
12	84785		Børgefjell	Nordland
13	84786		Bjørhusdal	Nord-Trøndelag
14	84787		Lyngveshøa	Oppland
15	84788		Netoseter	Oppland
16	84789		Hurdal	Akershus
17	84790		Nasafjell	Telemark
18	84791		Hattfjelldal	Nordland
19	84792		Lierne	Nord-Trøndelag
20	84793		Lierne	Nord-Trøndelag
21	84794		Lierne	Nord-Trøndelag
22	84795		Lierne	Nord-Trøndelag
23	84796		Lierne	Nord-Trøndelag

***Figure 5**: List of samples analysed in this study.*

Scanning electron microscopy

A SEM scans the surface of a specimen with a beam of accelerated electrons. In order to avoid interference from air molecules and other disturbances, the specimen is placed in a vacuum chamber. The intensity of the electrons reflected from the sample surface is measured by a secondary electron detector and used to produce images with a magnification of 20× to 20,000×. In addition to producing 3D images of the specimen surface by detecting secondary electrons, it is possible to detect areas of varying chemical content by detecting higher energy backscattered electrons (BSE). This result in images where areas composed of atoms of relatively high mean atomic number are bright, and darker in areas where the mean atomic number is lower (Frahm 2014).

In this study, the thin sections were investigated using an LEO 1450VP SEM, with an attached INCA energy-dispersive X-ray spectrometer (EDS), in order to document and identify (chemically) micro-inclusions (< 100 μm) of other minerals that may occur in the quartz crystals investigated. The type of micro-inclusion provides an additional criterion for distinguishing different provenance areas.

Scanning electron microscopy cathodoluminescence

The SEM-CL detector records photons (visible and invisible light) emitted from the sample when the electron beam hits and interacts with the sample surface. The energy (wavelength) of the detected photons is then translated into greyscale images. Contrasting grey-shades in SEM-CL images are caused by the heterogeneous distribution of various lattice defects, such as oxygen and silicon vacancies in the quartz crystal or broken bonds, and lattice-bound trace elements (Boggs and Krinsley 2006).

CL imaging of quartz crystals reveals structural traits relating to crystallisation, deformation and fluid-driven overprint (alteration) (Müller *et al.* 2018). Typical structures are micro-scale (< 1 mm) growth zoning, which can be compared to growth rings in a tree (though they do not indicate age in the same way). SEM-CL also reveals alteration structures and different quartz generations, such as crystal twinning and sub-grain formation, which are not visible on images produced by optical microscopy or BSE. These structures give insight into the growth and alteration history of quartz crystals. Additionally, the CL colour of quartz has been used to study its geological provenance (Boggs and Krinsley 2006). In archaeometric research, CL imaging has been applied to petrographic analyses of a wide range of materials (Szczepaniak 2014).

Laser ablation inductively coupled plasma mass spectrometry

ICP-MS instruments can be utilised for a variety of purposes in archaeology – such as raw material sourcing, determining isotopic ratios and age determination (Neff 2017). In LA-ICP-MS studies, the sample is placed in a near-vacuum chamber and ablated by a laser beam in order to free small particles from the sample surface. These particles (in our case quartz crystal fragments) are transported by an Ar–He gas mixture to the mass spectrometer where they are ionised into a plasma in order to determine the elemental composition of the sample by counting the ions with a detector.

LA-ICP-MS can determine element concentrations down to ppb (parts per billion), which makes it a high-precision tool for detecting trace elements (elements which make up less than 0.1% of the composition of a mineral or rock). One of the method's benefits for archaeologists is that it requires no sample preparation, which means that artefact samples can be analysed without being visibly destroyed. It will, however, leave a trace of the raster pattern of the laser beam, in our case 300 × 150 × 50 µm, though this is barely visible to the naked eye. Six LA-ICP-MS analyses were performed per sample along profiles across the quartz samples. The sampling spots were specifically located in different, CL-visualized growth zones in order to reveal possible chemical variations within the crystal.

In this study, LA-ICP-MS was used to analyse the concentrations of Li, Be, B, Al, P, Ti, Ca, Na, K, Mn, Fe and Ge, which are the most common trace elements found in natural quartz samples (e.g. Götze 2009). Six analyses were performed on each quartz crystal to reveal possible intra-crystal trace element variations. The analyses were conducted at the laboratories of NGU, using an Element 1 double-focusing sector field ICP-MS from Finnigan MAT. The results were processed in Microsoft Excel, using logarithmically scaled bivariate plots.

Results

The results are presented in the two following sections, one describing the structures visualised by SEM-CL in the quartz investigated, while the other focuses on the trace element content of quartz crystals.

Characterisation of cathodoluminescent structures in quartz crystals

Two of the quartz crystals analysed from Mohalsen-I (samples 1 and 4) revealed distinct structural traits that could be used in provenance studies. Sample 1 has an intense luminescent crystal core with weakly contrasted growth zoning (Fig. 6). The crystal margin shows strongly contrasted primary growth zoning with low CL intensity. In addition to this, tiny (< 200 μm) bright luminescent sub-crystals occur along the growth zone which separates the bright crystal core and the dull margin. Secondary structures include sporadic micro-fractures, healed with non-luminescent quartz. Similar to sample 1, sample 4 has a crystal core with strong CL intensity and weakly contrasted growth zoning and crystal twinning. Only a small part of the crystal edge is preserved in the sample, but the visible remains show weakly contrasted growth zoning with a low CL intensity. The visible secondary structures are similar to those of sample 1.

Samples 2 and 3, on the other hand, displayed a low CL intensity with no visible growth zoning. The CL images revealed a large amount of dull luminescent secondary quartz along and around healed micro-fractures. This secondary overprint is so strong that only a small volume of primary, more intense luminescent quartz is preserved. In general, the features are typical for quartz of igneous origin, and particularly for pegmatite quartz. However, the high abundance of these secondary, dark grey structures in both samples is not typical for pegmatitic quartz. These structures were likely enhanced by low-grade metamorphism or exposure to artificial heating, such as a bonfire.

Megacrystic (> 3 cm) pegmatite quartz is very abundant in Norway, in particular in South-Norway (e.g. Müller *et al.* 2017). Therefore, it is extremely challenging to trace the origin of these two pegmatite quartz samples, as their features are very similar, and it will not be possible to distinguish them from quartz from different Norwegian pegmatite localities. However, pegmatite quartz does not occur in the bedrock on Vega Island.

All hydrothermal crystals investigated from the 15 Norwegian quartz occurrences show distinct primary growth zoning of various patterns.

Sample 7 from Etne, sample 9 from Matskorhæ, sample 13 from Bjørhusdal and sample 14 from Lyngveshø have, in general, similar structures to that of sample 1 from Mohalsen-I: an intense luminescent crystal core, with weakly contrasted growth zoning overgrown by dull luminescent growth zones with strong contrast. However, hydrothermal samples from the Norwegian mainland do not have the distinct sub-crystals or the same type of secondary micro-fractures healed with non-luminescent quartz.

The remaining mainland samples displayed variable CL intensity and contrasted growth zoning, which is different to samples 1 and 4 from Mohalsen-1.

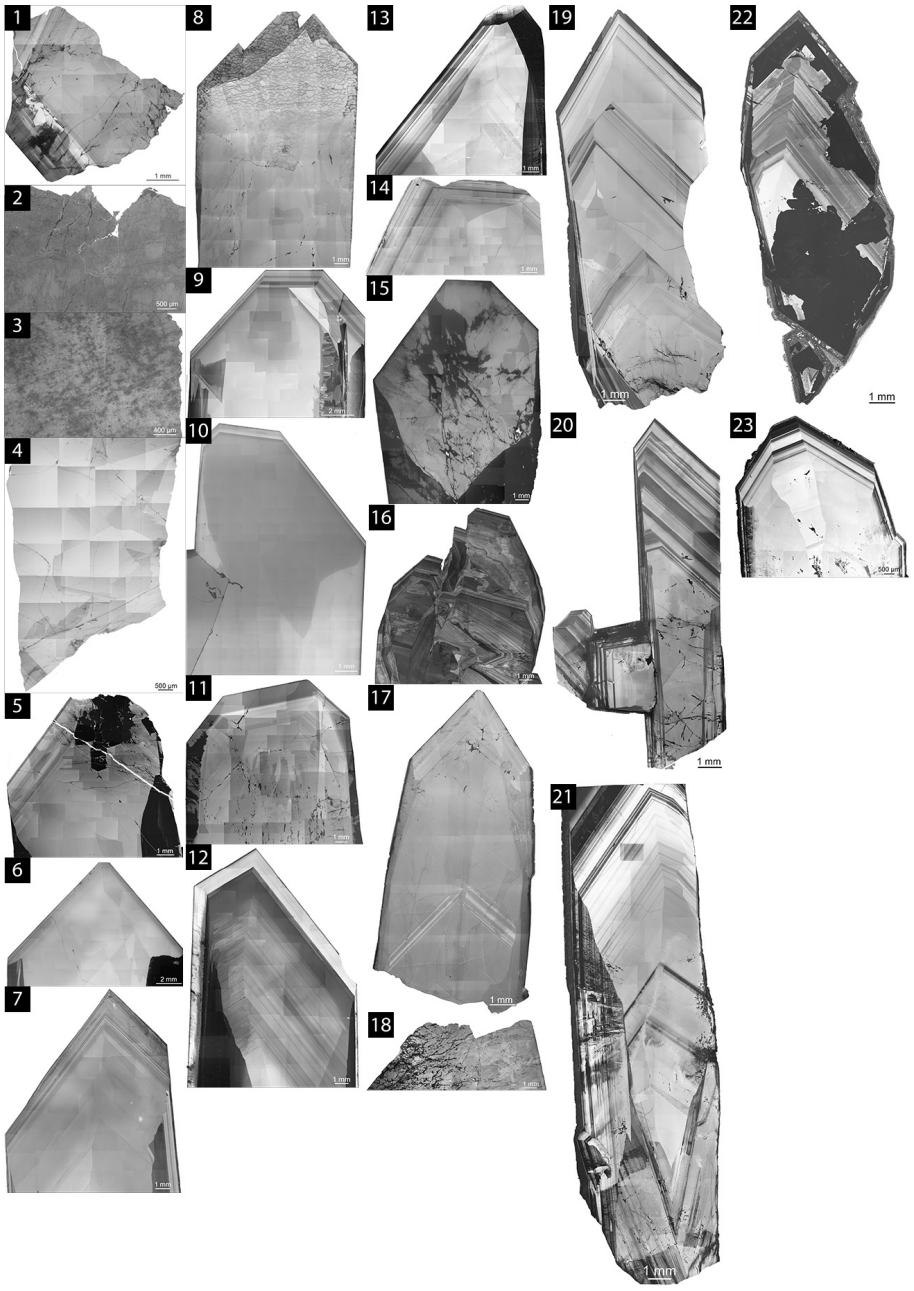

***Figure 6**: SEM-CL images of the quartz crystal analysed. Numbers correspond to sample numbers in Fig. 5. 1) Mohalsen-I, Nordland, 2) Mohalsen-I, Nordland, 3) Mohalsen-I, Nordland, 4) Mohalsen-I, Nordland, 5) Endenut, Hordaland, 6) Nibbenut, Hordaland, 7) Etne, Hordaland, 8) Svandalsflona, Telemark, 9) Matskorhæ, Hordaland, 10) Valdres, Oppland, 11) Vikafjell, Sogn og Fjordane, 12) Børgefjell, Nordland, 13) Bjørhusdal, Nord-Trøndelag, 14) Lyngveshøa, Oppland, 15) Netoseter, Oppland, 16) Hurdal, Akershus, 17) Nasafjell, Telemark, 18) Hattfjelldal, Nordland, 19–23) Berglia-Glassberget, Lierne, Nord-Trøndelag.*

The structural composition of the Lierne samples (s.nr. 14–19) all displayed similar characteristics: a high CL intensity in the crystal core and clearly delimited crystal edge, with highly contrasted growth zoning. Hydrothermal quartz of different origin is different in terms of structure. Thus, the cathodoluminescent structure seems to be indicative for a certain hydrothermal occurrence.

Quartz chemistry

All samples were successfully analysed using LA-ICP-MS to detect concentrations of common trace elements in quartz crystals. Ti, Al, Li and Ge were selected for further analysis, as these elements displayed a high degree of variation between the different occurrences (see appendix for detection limits (LOD) for each element).

Concentrations of Ti, Al, Li and Ge were similar for samples 1 and 4 from Mohalsen-I (Fig. 7a–7c and appendix). Sample 1 contained on average 6.3 ± 1.0 ppm Li, 1.9 ± 0.2 ppm Ge, 15.1 ± 1.9 ppm Al and 1.0 ± 0.6 ppm Ti. Sample 4 had 2.8 ± 0.4 ppm Li, 1.6 ± 0.1 ppm Ge, 16.9 ± 2.0 ppm Al and 1.0 ± 0.4 ppm Ti. This indicates that both quartz crystals could stem from the same quartz occurrence. Samples 2 and 3 contained a similar content of Li and Ge to samples 1 and 4, but their Al and Ti content were significantly higher.

Sample 9 from Matskorhæ contained similar, though somewhat lower, levels of Ti (0.6 ppm on average) and Ge (1.0 ppm on average) to samples 1 and 4. The Al (23.2 ppm) and Li (6.3 ppm) content had a relatively large standard variation (21.5 ppm and 5.7 ppm respectively), which means that the levels are within the range of samples 1 and 4 from Mohalsen-I. Additionally, the sample from Nibbenut (s.nr. 6) contained similar concentrations of Li (3.6 ± 2.3 ppm), Ge (1 ± 0.3 ppm), Al (14.3 ± 8.6 ppm) and Ti (0.54 ppm) to those of samples 1 and 4 from Mohalsen-I (see above and appendix).

The five samples from Lierne (s.nr. 19–23) displayed similar geochemical composition, with relatively high concentrations of Li and Al compared to the other samples. Sample 23 displayed spikes of Li and Al concentrations, resulting in a high standard deviation of the average measurement of the elements in this sample. The spikes could be explained by a large internal variation in chemical content. Additionally, there was some overlap in Li/Al content with the sample from Lyngveshøa (s.nr. 14): 129.5 ± 37.6 ppm Li and 1217.4 ± 517.7 ppm Al in the Lyngveshøa sample (s.nr. 14); and 78.3 ± 95.13 ppm Li and 558.3 ± 697 ppm Al for all the Lierne samples (s.nr. 19–23). However, the Lyngveshøa sample (s.nr. 14) displayed consistently higher concentrations of Li and Al, whereas the Lierne samples had a considerably higher degree of variation.

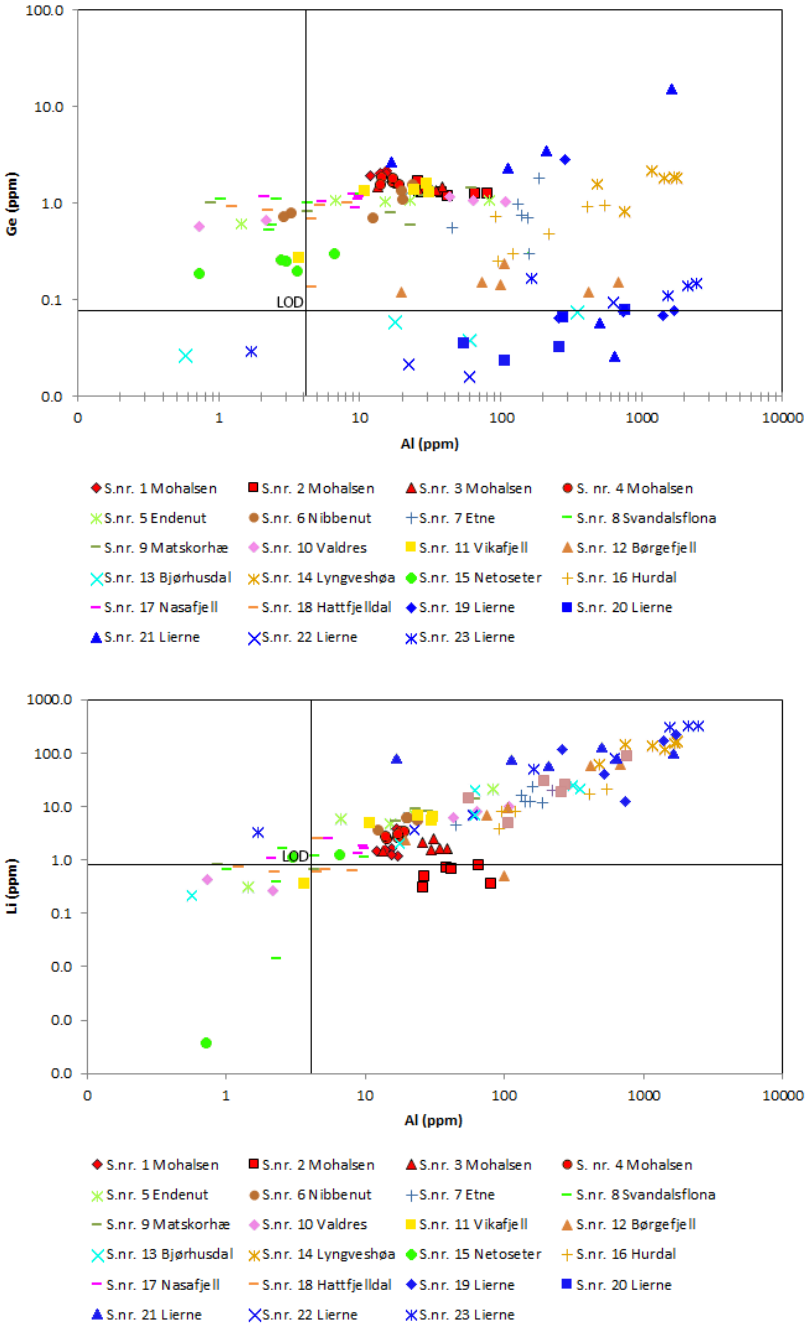

***Figure 7**: a) Bivariate plot showing Ge/Al content of quartz crystals analysed, b) bivariate plot showing Li/Al content of quartz crystals analysed,*

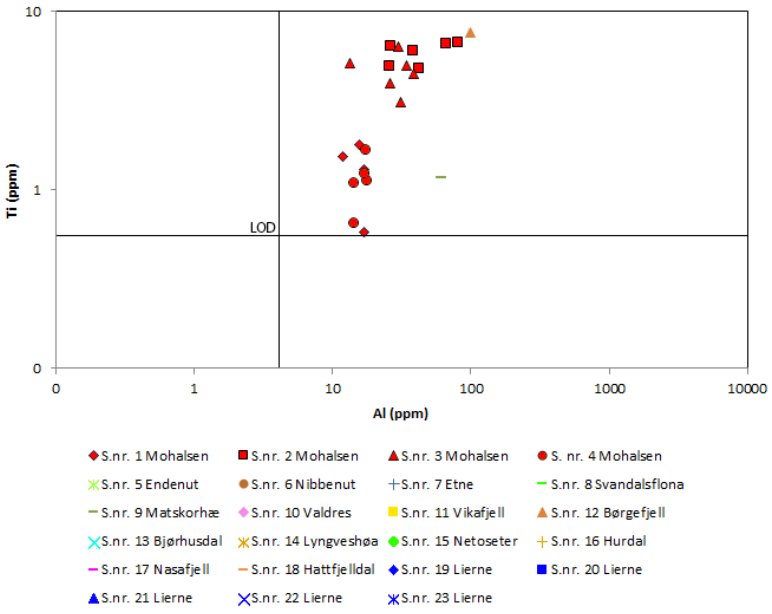

***Figure 7 (continued)**: c) bivariate plot showing Ti/Al content of quartz crystal analysed. LOD is marked in all plots with black lines.*

Discussion

Hydrothermal quartz crystal provenance studies – a viable approach?

The results from the LA-ICP-MS and SEM-CL analyses of the samples from Mohalsen-I (s.nr. 1–4) and selected quartz crystal outcrops (s.nr. 5–23), did not indicate a possible source for the quartz crystals from Vega Island. However, the concentrations of Al, Ti, Li and Ge in the samples (see Fig. 7a–7c) indicate that samples 1 and 4 formed under similar conditions and may come from the same quartz crystal occurrence. There were some structural and chemical similarities between samples 1 and 4, and sample 9, from Matskorhæ, but the results did not provide clear evidence to suggest this occurrence as a possible source.

Although the study was not able to detect a source for the quartz crystals used at Mohalsen-I, within a reasonable certainty, the method proved able to separate different hydrothermal quartz crystal occurrences. The five samples from Lierne displayed similar structural characteristics and geochemical composition, indicating that linking archaeological material to a known quartz crystal site is possible. However, there are several difficulties relating to such attempts. Many of these are 'classical' problems in provenance studies. First of all, it can be challenging to determine which sources were known and which were not in the period in question, and there is always the possibility that the sources which were utilised are depleted and thus not visible for us today. Furthermore, the material could have been found in redeposited sediments, such as riverbanks or moraines, or in areas outside national borders or area of investigation. Lastly, the internal geochemical variation in a quartz crystal occurrence could be too big to establish a secure 'signature' of the source (Andrews and Doonan 2003).

It is often said that it is easier to establish where a lithic material is not from than to establish a secure provenance (Andrews and Doonan 2003). As Shackley (1998, p. 261) puts it:

'One of the most misused terms in archaeometry is the word "sourcing". Archaeologists most often use it, and unfortunately, archaeometrists do too. Besides the grammatical problems with the word, it implies that whatever is submitted to the archaeometrist will return with a bona fide and certified source provenience that is not probabilistic at all, but confidently determined. I'm certainly not the first to say this, but I will reiterate that nothing is ever really "sourced".'

To mitigate some of these 'pitfalls', it is important to establish consistent sampling methodology and cooperation with geologists. In a review of lithic sourcing methods, Shackley (2017) presents eight steps to follow in provenance studies, which serve as a valuable guide to secure high-quality data collection. These guidelines could serve as a useful framework for future studies.

Another problem in provenance studies of archaeological artefacts is the use of destructive methods. In this study, thin sections were prepared of quartz crystal micro-debitage. This was done in order not to disturb refitting studies and other analyses of the material, such as use–wear analysis. Because so little of the crystal edge was preserved, it was difficult to assess the structural characteristics of the samples from Mohalsen-I. In relation to sourcing quartz crystals by combining petrography and geochemistry, this is a clear disadvantage. It must be a goal for future studies to include pieces where it can be confirmed that the crystal edge, and preferably parts of the crystal core, is preserved.

However, several instruments are being developed for fieldwork, making rock and mineral characterisation more accessible and less cost demanding than before. Portable SEMs are now being developed, with a high relevance for archaeological fieldwork. Relating to quartz crystals, this development is not as clear-cut. In order to establish the structural 'signature' of each occurrence, by characterising CL intensity and primary and secondary structures, we are so far dependent on producing thin sections for SEM-CL analysis.

The archaeological context – quartz crystals as a raw material and indication of mobility

Small amounts of quartz crystal seem to be present at several Early Mesolithic sites in western Norway (Waraas 2001). In central Norway, the tendency seems to be the same, with quartz crystal tools and debitage being present in small amounts at 91 of 261 Early Mesolithic sites listed by Breivik (2016), which were briefly analysed in relation to this article (6 of the total 267 listed sites were not available in online databases). This amounts to 35% of the sites, and quartz crystal is present in both coastal and inland assemblages. Most of the inland sites in the mountainous regions of Romsdal, Sunndal and Tafjord contained quartz crystal, whereas the picture was more varied on the coastal sites. The high mountain site Langfjelldal in Norddal County stands out with an assemblage dominated by quartz crystal (71%) (Ramstad 2014).

Waraas' (2001, p. 102) explanation for this tendency is that the large amount of quartz crystal on mountain sites in western Norway could be explained by the manufacture of tools which were brought back to the coast at the end of the hunting expedition. This will create a pattern

where the high mountain sites contain a large amount of quartz crystal debitage, whereas the coastal sites will only have tools and little waste material. However, it is interesting to note that seemingly few other raw materials have been utilised in these areas, such as milky quartz or quartzite and other sedimentary rock types. This could be explained by the special characteristics of quartz crystals. The important role of these alluring crystals among native peoples in various regions has been well documented in ethnographic accounts (e.g. Ball 1941, see also Broadbent 1979, p. 53). The symbolic and imagined magical capabilities of quartz crystals could well have been an important selective criterion in the Early Mesolithic, as both Waraas (2001) and others (Bang-Andersen 1998, Ramstad 2014) have pointed out.

However, it is difficult to assess both symbolic aspects and patterns of mobility from the Mohalsen-I assemblage, when no source has yet been identified. It seems unlikely that the quartz crystals in question have been found locally on Vega Island, indicating that they have been brought there by people. Following Binford's (1979) idea of 'embedded procurement', the raw material could have been collected during seasonal mobility routes or shorter hunting expeditions. In a pioneer phase, it seems unlikely that larger quarries or outcrops were exploited. This is supported by Nyland's (2016) recent work concerning rock quarries in southern Norway. She found no quarries that could be dated to the Early Mesolithic with reasonable certainty, though several appear during the Middle and Late Mesolithic. A chert quarry in Melsvik in Finnmark, however, seems to have been utilised by pioneer groups in the Early Mesolithic (Cerbing *et al.* 2019) – though somewhat later than the main occupation phase at Mohalsen-I. However, through the short analysis above it seems reasonable to conclude that the quartz crystals on Vega Island must have been found in nearby mountainous areas, such as the Lomsdal–Visten area, indicating utilisation of the inland area in the region.

Conclusion

The method applied here has a great potential to shed light on procurement strategies and mobility patterns in archaeological research. By examining four quartz samples from the Early Mesolithic site Mohalsen-I on Vega Island using SEM-CL and LA-ICP-MS, it was established that two of the samples (s.nr 2 and 3) were pegmatitic quartz, whereas the other two samples (s.nr. 1 and 4) consisted of hydrothermal quartz. This was based on a combination of interpretation of SEM-CL images and geochemistry. Samples 2 and 3 were probably exposed to artificial heating, most likely a bonfire or low-grade metamorphisation. Samples 1 and 4 displayed similar levels of the trace elements Al, Ti, Li and Ge (see Fig. 7a–7c), indicating that they stem from the same quartz crystal occurrence.

Hydrothermal quartz crystals were collected from 15 different occurrences in central and southern Norway, but none of these showed similar characteristics to the hydrothermal quartz crystal samples from Mohalsen-I (s.nr. 1 and 4) and thus no likely source could be established. However, after a short review of the occurrence of quartz crystals in Early Mesolithic assemblages in central Norway, it seems reasonable to conclude that a nearby mountainous region on the mainland, such as the Lomsdal–Visten area, is a possible source. Unfortunately, there are no quartz crystal occurrences yet known in this area containing > 5 cm quartz crystals.

Despite the negative results from the attempt to source the quartz crystal samples from Mohalsen-I, the study yielded positive results in relation to establishing a methodology for

the purpose. The five samples from the Berglia-Glassberget occurrence in Lierne displayed similar structural characteristics and trace element concentrations to each other, indicating that the method is a viable approach to sourcing hydrothermal quartz from archaeological contexts. However, in a future development of this line of research, there is clearly a need for a more thorough sampling to address the issue of intra-site chemical variability of a source.

Acknowledgements

We wish to thank Birgitte Skar for providing ^{14}C dates from Mohalsen-I and helpful comments on the manuscript. Kristoffer Grini and Jo Sindre Eidshaug revised the text and provided fruitful comments.

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Appendix

Table showing trace element data of analysed samples expressed in ppm. LOD for the selected elements are shown below each element. Averages and standard deviations are included as well.

Site/occurrence		Li7(LR)	Be9(LR)	B11(LR)	Mn55(LR)	Ge74(LR)	Rb85(LR)	Sr88(LR)	Na23(MR)	Al27(MR)	P31(MR)	K39(MR)	Ca44(MR)	Ti47(MR)	Fe56(MR)
	LOD	0,78	0,45	1,41	0,17	0,07	0,10	0,03	7,94	4,21	5,02	20,41	6,32	0,54	0,51
S.nr. 1 Mohalsen	581-A	3,73	0,45	1,41	0,17	1,65	0,10	0,06	114,30	16,84	5,02	20,41	6,32	1,31	0,51
	581-B	1,47	0,45	1,41	0,17	1,91	0,10	0,10	7,94	12,00	5,02	20,41	6,32	1,53	0,51
	581-C	1,66	0,45	1,41	0,21	2,20	0,10	0,05	7,94	15,53	5,02	20,41	6,32	1,81	0,51
	581-D	1,20	0,45	1,41	0,49	1,74	0,10	0,06	7,94	17,05	5,02	20,41	6,32	0,58	0,51
	581-E	1,51	0,45	1,45	0,31	2,07	0,10	0,07	7,94	13,92	5,02	20,41	6,32	0,54	0,51
	581-F	1,22	0,45	1,41	0,17	2,04	0,10	0,04	7,94	15,45	5,02	20,41	6,32	0,54	0,51
	average	1,80	0,45	1,42	0,25	1,93	0,10	0,06	25,67	15,13	5,02	20,41	6,32	1,05	0,51
	STD	0,96	0,00	0,02	0,13	0,21	0,00	0,02	43,42	1,91	0,00	0,00	0,00	0,57	0,00
S.nr. 2 Mohalsen	590-A	0,78	0,45	1,41	0,27	1,65	0,10	0,10	7,94	26,16	5,02	20,41	6,32	4,95	0,62
	590-B	0,78	0,45	1,46	0,20	1,23	0,10	0,10	7,94	82,13	5,02	20,41	6,32	6,67	1,25
	590-C	0,78	0,45	1,41	0,30	1,24	0,10	0,08	7,94	66,41	5,02	26,33	6,32	6,61	0,51
	590-D	0,78	0,45	2,22	0,38	1,29	0,10	0,20	7,94	38,84	5,02	20,41	6,32	5,99	0,51
	590-E	0,78	0,45	1,41	0,20	1,17	0,10	0,08	7,94	42,53	5,02	20,41	6,32	4,77	0,51
	590-F	0,78	0,45	1,59	0,23	1,27	0,10	0,10	7,94	26,65	5,02	20,41	6,32	6,33	0,51
	average	0,78	0,45	1,58	0,26	1,31	0,10	0,11	7,94	47,12	5,02	21,40	6,32	5,89	0,65
	STD	0,00	0,00	0,32	0,07	0,17	0,00	0,04	0,00	22,56	0,00	2,42	0,00	0,84	0,30
S.nr. 3 Mohalsen	591a-A	2,56	0,45	1,41	0,17	1,47	0,10	0,06	17,05	31,18	5,02	20,41	6,32	3,12	0,51
	591a-B	1,43	0,45	1,41	0,21	1,48	0,10	0,05	7,94	13,37	5,02	20,41	6,32	5,15	0,51
	591a-C	1,52	0,45	1,41	0,22	1,39	0,10	0,06	7,94	30,02	5,02	20,41	6,32	6,41	0,51
	591a-D	1,62	0,45	1,41	0,17	1,49	0,10	0,04	7,94	38,83	5,02	20,41	6,70	4,49	0,51
	591a-E	1,64	0,45	1,41	0,24	1,34	0,10	0,05	7,94	34,68	5,02	20,41	6,32	5,01	0,51
	591a-F	2,10	0,45	1,41	0,25	1,36	0,10	0,05	7,94	26,09	5,02	20,41	6,32	3,99	0,51
	average	1,81	0,45	1,41	0,21	1,42	0,10	0,05	9,46	29,03	5,02	20,41	6,38	4,69	0,51
	STD	0,43	0,00	0,00	0,03	0,07	0,00	0,01	3,72	8,80	0,00	0,00	0,16	1,12	0,00
S. nr. 4 Mohalsen	591b-A	3,24	0,45	1,41	0,17	1,59	0,10	0,04	7,94	18,13	5,02	20,41	6,32	1,13	0,51
	591b-B	2,35	0,45	1,41	0,21	1,81	0,10	0,05	7,94	14,54	5,02	20,41	6,32	0,64	0,51
	591b-C	2,67	0,45	1,59	0,17	1,55	0,10	0,06	7,94	14,37	5,02	20,41	6,32	1,09	0,51

Site/occurrence		Li7(LR)	Be9(LR)	B11(LR)	Mn55(LR)	Ge74(LR)	Rb85(LR)	Sr88(LR)	Na23(MR)	Al27(MR)	P31(MR)	K39(MR)	Ca44(MR)	Ti47(MR)	Fe56(MR)
	591b-D	2,54	0,45	1,41	0,18	1,62	0,10	0,03	7,94	17,39	5,02	20,41	6,32	1,23	0,51
	591b-E	3,30	0,45	1,41	0,25	1,53	0,10	0,04	7,94	19,44	5,02	20,41	6,32	0,54	0,51
	591b-F	2,87	0,45	1,44	0,21	1,76	0,10	0,06	7,94	17,53	5,02	20,41	6,32	1,67	0,51
	average	2,83	0,45	1,44	0,20	1,64	0,10	0,05	7,94	16,90	5,02	20,41	6,32	1,05	0,51
	STD	0,38	0,00	0,07	0,03	0,11	0,00	0,01	0,00	2,03	0,00	0,00	0,00	0,41	0,00
S.nr. 5 Endenut	84777-A	21,40	0,45	1,41	0,54	1,07	0,10	0,07	7,94	83,50	10,57	20,41	7,75	0,54	0,87
	84777-B	4,81	0,45	1,41	0,28	1,05	0,10	0,10	7,94	15,26	5,02	20,41	6,32	0,54	0,51
	84777-C	6,24	0,45	1,41	0,27	1,19	0,10	0,07	7,94	20,74	5,02	20,41	6,32	0,54	0,51
	84777-D	6,82	0,45	1,41	0,34	1,09	0,10	0,13	7,94	22,63	5,02	20,41	6,32	0,54	0,51
	84777-E	5,85	0,45	1,41	0,24	1,09	0,10	0,06	7,94	6,76	5,02	20,41	6,32	0,54	0,51
	84777-F	0,78	0,45	1,41	0,37	0,61	0,10	0,07	7,94	4,21	5,15	20,41	6,32	0,54	0,51
	average	7,65	0,45	1,41	0,34	1,01	0,10	0,08	7,94	25,51	5,97	20,41	6,56	0,54	0,57
	STD	7,07	0,00	0,00	0,11	0,20	0,00	0,03	0,00	29,34	2,26	0,00	0,58	0,00	0,15
S.nr. 6 Nibbenut	84779-A	3,37	0,45	1,41	0,43	0,69	0,10	0,10	7,94	12,71	5,02	20,41	6,32	0,54	0,53
	84779-B	5,83	0,45	1,41	0,27	1,08	0,10	0,10	7,94	20,54	5,02	20,41	6,32	0,54	0,51
	84779-C	5,85	0,45	1,41	0,30	1,34	0,10	0,07	7,94	20,10	5,02	20,41	8,51	0,54	0,51
	84779-D	5,23	0,45	1,41	0,26	1,53	0,10	0,09	7,94	24,08	5,02	20,41	6,32	0,54	0,51
	84779-E	0,78	0,45	1,41	0,47	0,79	0,10	0,07	7,94	4,21	7,46	20,41	6,32	0,54	0,51
	84779-F	0,78	0,45	1,41	0,28	0,70	0,10	0,03	7,94	4,21	5,02	20,41	6,32	0,54	0,51
	average	3,64	0,45	1,41	0,33	1,02	0,10	0,08	7,94	14,31	5,43	20,41	6,69	0,54	0,51
	STD	2,39	0,00	0,00	0,09	0,36	0,00	0,03	0,00	8,65	1,00	0,00	0,89	0,00	0,01
S.nr. 7 Etne	84780-A	4,38	0,45	1,41	0,58	0,57	0,10	0,03	7,94	45,24	5,02	20,41	6,32	0,54	0,51
	84780-B	11,59	0,45	1,41	0,22	1,83	0,10	0,03	7,94	187,21	5,02	20,41	6,32	0,54	0,51
	84780-C	15,84	0,45	1,41	0,34	0,97	0,10	0,05	7,94	132,33	5,02	20,41	6,32	0,54	0,51
	84780-D	12,59	0,45	1,41	0,21	0,71	0,10	0,03	7,94	154,49	5,02	20,41	6,32	0,54	0,51
	84780-E	12,49	0,45	1,41	0,31	0,76	0,10	0,06	7,94	140,25	5,02	20,41	6,32	0,54	0,51
	84780-F	23,93	0,45	1,41	0,24	0,31	0,10	0,08	7,94	159,92	5,21	20,41	6,32	0,54	0,51
	average	13,47	0,45	1,41	0,32	0,86	0,10	0,05	7,94	136,57	5,05	20,41	6,32	0,54	0,51
	STD	6,37	0,00	0,00	0,14	0,52	0,00	0,02	0,00	48,59	0,08	0,00	0,00	0,00	0,00
S.nr. 8 Svandalsflona	84781-A	0,78	0,45	1,41	0,58	0,59	0,10	0,03	7,94	4,21	5,02	20,41	6,32	0,54	0,51
	84781-B	0,78	0,45	1,41	0,29	0,53	0,10	0,06	7,94	4,21	5,02	20,41	20,47	0,54	0,51
	84781-C	1,14	0,45	1,41	0,29	1,25	0,10	0,05	7,94	9,50	5,02	20,41	6,32	0,54	0,51
	84781-D	1,61	0,45	1,41	0,33	1,12	0,10	0,05	7,94	4,21	5,02	20,41	6,99	0,54	0,51

Site/occurrence		Li7(LR)	Be9(LR)	B11(LR)	Mn55(LR)	Ge74(LR)	Rb85(LR)	Sr88(LR)	Na23(MR)	Al27(MR)	P31(MR)	K39(MR)	Ca44(MR)	Ti47(MR)	Fe56(MR)
	84781-E	0,78	0,45	1,41	0,24	1,10	0,10	0,09	7,94	4,21	5,02	20,41	11,66	0,54	0,51
	84781-F	1,20	0,45	1,41	0,37	1,01	0,10	0,10	7,94	4,21	5,02	20,41	7,12	0,54	0,51
	average	1,05	0,45	1,41	0,35	0,93	0,10	0,06	7,94	5,09	5,02	20,41	9,81	0,54	0,51
	STD	0,34	0,00	0,00	0,12	0,30	0,00	0,03	0,00	2,16	0,00	0,00	5,60	0,00	0,00
S.nr. 9 Matskorhæ	84782-A	8,89	0,45	1,41	0,17	0,60	0,10	0,07	7,94	23,10	5,02	20,41	6,32	0,54	0,51
	84782-B	5,14	0,45	1,41	0,20	0,81	0,10	0,07	7,94	16,65	5,02	20,41	6,32	0,54	0,51
	84782-C	14,11	0,45	1,41	0,24	1,46	0,10	0,09	7,94	62,17	5,02	20,41	6,32	1,16	0,51
	84782-D	8,22	0,45	1,41	0,21	1,22	0,10	0,10	7,94	28,79	5,02	20,41	6,32	0,54	0,51
	84782-E	0,81	0,45	1,41	0,26	1,02	0,10	0,07	7,94	4,21	5,02	20,41	6,32	0,54	0,51
	84782-F	0,78	0,45	1,41	0,27	0,82	0,10	0,08	7,94	4,31	5,02	20,41	6,32	0,54	0,51
	average	6,33	0,45	1,41	0,22	0,99	0,10	0,08	7,94	23,21	5,02	20,41	6,32	0,64	0,51
	STD	5,17	0,00	0,00	0,04	0,31	0,00	0,01	0,00	21,50	0,00	0,00	0,00	0,25	0,00
S.nr. 10 Valdres	84783-A	9,97	0,45	1,41	0,22	1,03	0,10	0,03	7,94	109,22	5,02	20,41	9,42	0,54	0,51
	84783-B	6,12	0,45	1,41	0,25	1,19	0,10	0,03	7,94	43,31	5,27	20,41	6,32	0,54	0,51
	84783-C	8,01	0,45	1,41	0,27	1,08	0,10	0,03	7,94	63,73	5,02	20,41	6,32	0,54	0,51
	84783-D	0,78	0,45	1,41	0,23	0,57	0,10	0,05	7,94	4,21	5,02	20,41	6,32	0,54	0,51
	84783-E	0,78	0,45	1,41	0,27	0,68	0,10	0,04	7,94	4,21	5,02	20,41	20,49	0,54	0,51
	84783-F	0,78	0,45	1,41	0,29	0,58	0,10	0,07	7,94	4,21	5,02	20,41	11,10	0,54	0,51
	average	4,41	0,45	1,41	0,26	0,85	0,10	0,04	7,94	38,15	5,06	20,41	9,99	0,54	0,51
	STD	4,16	0,00	0,00	0,02	0,27	0,00	0,02	0,00	42,86	0,10	0,00	5,52	0,00	0,00
S.nr. 11 Vikafjell	84784-A	1,74	0,45	1,41	0,17	0,34	0,10	0,03	7,94	4,21	5,09	20,41	6,32	0,54	0,51
	84784-B	6,52	0,45	1,41	0,27	1,35	0,10	0,08	7,94	24,42	5,02	20,41	6,32	0,54	0,51
	84784-C	6,10	0,45	1,41	0,25	1,26	0,10	0,03	7,94	31,18	5,02	20,41	6,32	0,54	0,51
	84784-D	5,32	0,45	1,41	0,45	1,58	0,10	0,09	7,94	30,14	5,02	20,41	6,32	0,54	0,51
	84784-E	4,64	0,45	1,41	0,26	1,34	0,10	0,04	7,94	11,04	5,02	20,41	6,32	0,54	0,51
	84784-F	0,78	0,45	1,41	0,34	0,27	0,10	0,08	7,94	4,21	5,02	20,41	6,32	0,54	0,51
	average	4,18	0,45	1,41	0,29	1,02	0,10	0,06	7,94	17,53	5,03	20,41	6,32	0,54	0,51
	STD	2,37	0,00	0,00	0,10	0,56	0,00	0,03	0,00	12,57	0,03	0,00	0,00	0,00	0,00
S.nr. 12 Børgefjell	84785-A	59,52	0,45	1,41	0,17	0,12	0,10	0,22	7,94	422,32	5,02	20,41	6,32	0,54	0,51
	84785-B	59,88	0,45	1,41	0,39	0,15	0,10	1,51	7,94	684,44	5,02	20,41	17,21	0,54	0,51
	84785-C	2,35	0,45	1,41	0,38	0,12	0,10	0,04	7,94	19,55	5,02	20,41	6,32	0,54	0,51
	84785-D	9,34	0,45	1,41	0,34	0,24	0,10	0,04	7,94	105,22	5,02	20,41	6,32	0,54	0,51
	84785-E	6,97	0,45	1,41	0,30	0,15	0,10	0,03	7,94	74,34	5,02	20,41	8,58	0,54	0,51
	84785-F	0,78	2,21	1,41	1,11	0,14	0,10	0,17	64,82	99,98	5,02	20,41	12,26	7,68	64,47

Site/occurrence		Li7(LR)	Be9(LR)	B11(LR)	Mn55(LR)	Ge74(LR)	Rb85(LR)	Sr88(LR)	Na23(MR)	Al27(MR)	P31(MR)	K39(MR)	Ca44(MR)	Ti47(MR)	Fe56(MR)
	average	23,14	0,74	1,41	0,45	0,15	0,10	0,34	17,42	234,31	5,02	20,41	9,50	1,73	11,17
	STD	28,49	0,72	0,00	0,33	0,04	0,00	0,58	23,22	262,45	0,00	0,00	4,43	2,92	26,11
S.nr. 13 Bjørhusdal	84786-A	20,24	0,45	1,41	0,38	0,04	0,10	0,07	7,94	61,55	5,02	20,41	6,32	0,54	0,51
	84786-B	6,97	0,45	1,41	0,36	0,04	0,10	0,12	7,94	60,71	5,02	20,41	21,90	0,54	0,51
	84786-C	2,06	0,45	1,41	0,21	0,06	0,10	0,06	7,94	17,83	5,02	20,41	20,56	0,54	1,99
	84786-D	0,78	0,45	1,41	0,40	0,03	0,10	0,08	7,94	4,21	6,48	20,41	6,32	0,54	0,51
	84786-E	24,66	0,45	1,41	0,31	0,00	0,10	0,04	7,94	316,71	11,19	20,41	6,32	0,54	0,51
	84786-F	20,99	0,45	1,41	0,36	0,08	0,10	0,03	7,94	347,95	5,02	20,41	8,55	0,54	0,51
	average	12,62	0,45	1,41	0,34	0,04	0,10	0,07	7,94	134,83	6,29	20,41	11,66	0,54	0,76
	STD	10,55	0,00	0,00	0,07	0,03	0,00	0,03	0,00	154,99	2,47	0,00	7,47	0,00	0,60
S.nr. 14 Lyngveshøa	84787-A	143,86	0,45	1,41	0,41	0,82	0,10	0,08	7,94	749,32	5,02	20,41	6,32	0,54	0,51
	84787-B	59,91	0,45	1,41	0,37	1,59	0,10	0,04	7,94	482,01	5,02	20,41	6,32	0,54	0,51
	84787-C	139,66	0,45	1,41	0,37	2,16	0,10	0,03	7,94	1171,25	5,02	20,41	6,32	0,54	0,51
	84787-D	115,95	0,45	1,41	0,34	1,80	0,10	0,09	7,94	1442,28	5,02	20,41	6,32	0,54	0,51
	84787-E	162,92	0,45	1,56	0,41	1,84	0,10	0,04	7,94	1761,90	6,24	20,41	18,27	0,54	0,51
	84787-F	154,71	0,45	1,41	0,44	1,86	0,10	0,09	7,94	1698,07	5,02	20,41	6,32	0,54	0,51
	average	129,50	0,45	1,44	0,39	1,68	0,10	0,06	7,94	1217,47	5,22	20,41	8,31	0,54	0,51
	STD	37,65	0,00	0,06	0,04	0,46	0,00	0,03	0,00	517,71	0,50	0,00	4,88	0,00	0,00
S.nr. 15 Netoseter	84788-A	0,78	0,45	1,41	0,54	0,22	0,10	0,08	7,94	4,21	5,02	20,41	6,32	0,54	0,51
	84788-B	0,78	0,45	1,41	0,34	0,18	0,10	0,06	7,94	4,21	5,02	20,41	6,32	0,54	0,51
	84788-C	1,06	0,45	1,41	0,35	0,24	0,10	0,03	7,94	4,21	5,02	20,41	6,32	0,54	0,51
	84788-D	1,18	0,45	1,41	0,25	0,29	0,10	0,05	7,94	6,74	5,02	20,41	6,32	0,54	0,51
	84788-E	0,78	0,45	1,41	0,47	0,19	0,10	0,03	7,94	4,21	5,02	20,41	6,32	0,54	0,51
	84788-F	0,78	0,45	1,41	0,31	0,25	0,10	0,03	7,94	4,21	5,02	20,41	6,32	0,54	0,51
	average	0,89	0,45	1,41	0,38	0,23	0,10	0,05	7,94	4,63	5,02	20,41	6,32	0,54	0,51
	STD	0,18	0,00	0,00	0,11	0,04	0,00	0,02	0,00	1,03	0,00	0,00	0,00	0,00	0,00
S.nr. 16 Hurdal	84789-A	3,76	0,45	1,41	0,17	0,74	0,10	0,06	7,94	91,49	5,02	20,41	6,32	0,54	0,51
	84789-B	16,83	0,45	1,41	0,35	0,94	0,10	0,14	7,94	413,65	5,02	20,41	6,32	0,54	0,51
	84789-C	7,99	0,45	1,41	0,32	0,30	0,10	0,06	7,94	121,19	7,85	20,41	6,32	0,54	0,51
	84789-D	7,87	0,45	1,41	0,26	0,25	0,10	0,04	7,94	95,74	5,02	20,41	16,62	0,54	0,51
	84789-E	20,85	0,45	1,41	0,31	0,97	0,10	0,22	7,94	545,31	5,02	20,41	6,32	0,54	0,51
	84789-F	19,92	0,45	1,41	0,33	0,49	0,10	0,06	7,94	221,99	7,58	20,41	6,32	0,54	0,51
	average	12,87	0,45	1,41	0,29	0,61	0,10	0,10	7,94	248,23	5,92	20,41	8,04	0,54	0,51

Site/occurrence		Li7(LR)	Be9(LR)	B11(LR)	Mn55(LR)	Ge74(LR)	Rb85(LR)	Sr88(LR)	Na23(MR)	Al27(MR)	P31(MR)	K39(MR)	Ca44(MR)	Ti47(MR)	Fe56(MR)
	STD	7,22	0,00	0,00	0,07	0,31	0,00	0,07	0,00	189,88	1,40	0,00	4,20	0,00	0,00
S.nr. 17 Nasafjell	84790-A	2,45	0,45	1,41	0,37	1,05	0,10	0,05	7,94	5,13	5,02	20,41	6,32	0,54	0,51
	84790-B	1,06	0,45	1,41	0,29	1,16	0,10	0,03	7,94	4,21	5,02	20,41	11,68	0,54	0,51
	84790-C	1,83	0,45	1,41	0,17	0,90	0,10	0,04	7,94	9,30	5,02	20,41	6,32	0,54	0,51
	84790-D	1,31	0,45	1,41	0,38	1,23	0,10	0,03	7,94	8,51	9,40	20,41	15,84	0,54	0,51
	84790-E	1,71	0,45	1,41	0,26	1,10	0,10	0,04	7,94	9,32	5,02	20,41	6,32	0,54	0,51
	84790-F	1,61	0,45	1,41	0,27	1,17	0,10	0,04	7,94	9,57	7,95	20,41	8,80	0,54	0,51
	average	1,66	0,45	1,41	0,29	1,10	0,10	0,04	7,94	7,67	6,24	20,41	9,21	0,54	0,51
	STD	0,48	0,00	0,00	0,08	0,12	0,00	0,01	0,00	2,37	1,94	0,00	3,88	0,00	0,00
S.nr. 18 Hattfjelldal	84791-A	2,45	0,45	2,79	0,17	0,14	0,10	0,03	7,94	4,62	5,25	20,41	6,32	0,54	0,51
	84791-B	0,78	0,45	1,41	0,32	0,68	0,10	0,03	7,94	4,56	6,14	20,41	6,32	0,54	0,51
	84791-C	0,78	0,45	1,41	0,30	0,95	0,10	0,04	7,94	5,25	6,27	20,41	6,32	0,54	0,51
	84791-D	0,78	0,45	1,41	0,33	0,84	0,10	0,05	7,94	4,21	5,02	20,41	6,32	0,54	0,51
	84791-E	0,78	0,45	1,41	0,41	0,93	0,10	0,03	7,94	4,21	5,02	20,41	6,32	0,54	0,51
	84791-F	0,78	0,45	1,41	0,31	1,01	0,10	0,07	7,94	8,24	5,02	20,41	33,63	0,54	0,97
	average	1,06	0,45	1,64	0,31	0,76	0,10	0,04	7,94	5,18	5,45	20,41	10,87	0,54	0,59
	STD	0,68	0,00	0,57	0,08	0,33	0,00	0,02	0,00	1,54	0,59	0,00	11,15	0,00	0,19
S.nr. 19 Lierne	84792-A	25,97	0,45	1,41	0,24	2,83	0,10	0,06	7,94	284,33	5,02	20,41	6,32	0,54	0,51
	84792-B	217,87	0,45	1,41	0,22	0,08	0,10	0,12	7,94	1707,56	5,02	20,41	6,32	0,54	0,51
	84792-C	115,27	0,45	1,41	0,63	0,07	0,10	0,14	7,94	260,63	5,02	20,41	11,53	0,54	0,51
	84792-D	41,13	0,45	1,41	0,28	0,07	0,10	0,03	7,94	521,45	5,34	20,41	6,32	0,54	0,51
	84792-E	12,53	0,45	1,41	0,27	0,08	0,10	0,03	7,94	742,22	10,01	20,41	13,90	0,54	0,51
	84792-F	165,18	0,45	1,41	0,27	0,07	0,10	0,03	7,94	1408,90	5,02	20,41	6,32	0,54	0,51
	average	96,33	0,45	1,41	0,32	0,53	0,10	0,07	7,94	820,85	5,91	20,41	8,45	0,54	0,51
	STD	83,54	0,00	0,00	0,15	1,13	0,00	0,05	0,00	604,91	2,02	0,00	3,39	0,00	0,00
S.nr. 20 Lierne	84793-A	24,33	0,45	1,41	0,17	0,07	0,10	0,09	7,94	278,09	6,71	20,41	6,32	0,54	0,51
	84793-B	14,15	0,45	1,41	0,40	0,07	0,10	0,09	7,94	55,69	7,23	20,41	6,32	0,54	0,51
	84793-C	4,77	0,45	1,41	0,28	0,07	0,10	0,05	7,94	109,04	8,17	20,41	6,32	0,54	0,51
	84793-D	18,12	0,45	1,41	0,25	0,07	0,10	0,04	7,94	262,56	5,42	20,41	6,95	0,54	0,51
	84793-E	83,86	0,45	1,41	0,36	0,08	0,10	0,03	7,94	775,47	8,12	20,41	45,43	0,54	0,51
	84793-F	28,71	0,45	1,41	0,36	0,07	0,10	0,14	7,94	196,26	6,98	20,41	6,32	0,54	0,51
	average	28,99	0,45	1,41	0,30	0,07	0,10	0,07	7,94	279,52	7,11	20,41	12,94	0,54	0,51
	STD	28,13	0,00	0,00	0,09	0,00	0,00	0,04	0,00	257,82	1,02	0,00	15,92	0,00	0,00
S.nr. 21 Lierne	84794-A	96,81	0,45	1,41	0,17	15,03	0,14	0,15	7,94	1634,26	5,02	20,41	6,32	0,54	0,51

Site/occurrence		Li7(LR)	Be9(LR)	B11(LR)	Mn55(LR)	Ge74(LR)	Rb85(LR)	Sr88(LR)	Na23(MR)	Al27(MR)	P31(MR)	K39(MR)	Ca44(MR)	Ti47(MR)	Fe56(MR)
	84794-B	59,27	0,45	1,41	0,28	3,45	0,10	0,07	7,94	210,58	5,02	20,41	6,32	0,54	0,51
	84794-C	79,06	0,45	1,41	0,32	0,07	0,10	0,07	7,94	643,31	5,21	20,41	13,74	0,54	0,51
	84794-D	128,05	0,45	1,41	0,46	0,07	0,21	0,18	7,94	505,14	5,02	20,41	6,32	0,54	2,10
	84794-E	76,50	0,45	1,41	0,28	2,29	0,10	0,10	7,94	112,07	5,02	20,41	22,56	0,54	0,51
	84794-F	80,04	0,45	1,41	0,38	2,71	0,10	0,10	7,94	16,71	5,02	20,41	6,32	0,54	0,51
	average	86,62	0,45	1,41	0,32	3,94	0,13	0,11	7,94	520,35	5,05	20,41	10,26	0,54	0,77
	STD	23,54	0,00	0,00	0,10	5,61	0,04	0,04	0,00	595,39	0,08	0,00	6,72	0,00	0,65
S.nr. 22 Lierne	84795-A	0,78	0,45	1,41	0,41	0,29	0,10	0,04	7,94	4,21	5,02	20,41	21,37	0,54	0,51
	84795-B	0,78	0,45	1,41	0,38	0,07	0,10	0,06	7,94	4,21	5,02	20,41	6,32	0,54	0,51
	84795-C	6,79	0,45	1,41	0,38	0,07	0,10	0,03	7,94	59,77	5,89	20,41	29,78	0,54	0,51
	84795-D	3,69	0,45	1,41	0,39	0,07	0,10	0,05	7,94	22,42	5,02	20,41	6,32	0,54	0,51
	84795-E	80,00	0,45	1,41	0,29	0,09	0,10	0,03	7,94	633,19	5,02	20,41	6,32	0,54	0,51
	84795-F	0,04	0,45	1,41	0,26	0,08	0,10	0,03	7,94	4,21	5,02	20,41	11,40	0,54	0,51
	average	15,35	0,45	1,41	0,35	0,11	0,10	0,04	7,94	121,34	5,17	20,41	13,59	0,54	0,51
	STD	31,77	0,00	0,00	0,06	0,09	0,00	0,01	0,00	251,68	0,36	0,00	9,86	0,00	0,00
S.nr. 23 Lierne	84796-A	0,78	0,45	1,41	0,56	0,70	0,10	0,04	7,94	4,21	5,02	20,41	6,32	0,54	0,51
	84796-B	50,58	0,45	1,41	0,23	0,17	0,10	0,05	7,94	163,97	5,02	20,41	6,32	0,54	0,51
	84796-C	316,18	0,45	1,41	0,26	0,14	0,10	0,07	9,60	2104,79	7,52	20,41	6,32	0,54	0,51
	84796-D	319,32	0,45	1,41	0,42	0,15	0,10	0,15	7,94	2471,34	5,02	20,41	6,32	0,54	0,51
	84796-E	297,21	0,45	1,41	0,37	0,11	0,10	0,11	7,94	1549,65	5,02	20,41	6,32	0,54	0,51
	84796-F	3,22	0,45	1,41	0,40	0,07	0,10	0,03	7,94	4,21	5,02	20,41	6,32	0,54	0,51
	average	164,55	0,45	1,41	0,37	0,22	0,10	0,07	8,22	1049,70	5,44	20,41	6,32	0,54	0,51
	STD	161,48	0,00	0,00	0,12	0,24	0,00	0,05	0,68	1127,37	1,02	0,00	0,00	0,00	0,00
Lierne all	average	78,37	0,45	1,41	0,33	0,97	0,11	0,07	8,00	558,35	5,73	20,41	10,31	0,54	0,56
	STD	95,13	0,00	0,00	0,10	2,82	0,02	0,04	0,30	697,01	1,29	0,00	8,82	0,00	0,29

In this volume, 10 papers from the Stone Age Conference in Bergen 2017 are presented. They range thematically from the earliest pioneer phase in the Mesolithic to the Neolithic and Bronze Age in the high mountains. The papers discuss new research and methodological developments showing a diverse and dynamic Stone Age research community in Norway.

ISBN: 978-82-8436-002-7